

Multiplier device.

The invention relates to a multiplier device comprising first to n^{th} multipliers M_1 to M_n for multiplying a carrier modulated information signal with first to n^{th} mutually
5 phase shifted and identical, substantially square wave mixing signals MS_1 to MS_n with 50% duty cycle. Such multiplier devices are frequently used in receivers for converting an RF antenna input signal with an RF carrier frequency f_{RF} into an intermediate frequency (IF) signal with an IF carrier frequency f_{IF} and/or for demodulating an (IF) carrier modulated information signal with carrier frequency f_c
10 into baseband, or as used in stereodecoder circuits for decoding and/or demultiplexing a stereo multiplex signal into left and right baseband stereosignals.

A stereodecoder circuit using such multiplier device to demodulate a stereo difference signal (L-R) double sideband amplitude modulated on a subcarrier f_c of 38 kHz into baseband, is e.g. known from US patent 3,962,551. This known multiplier
15 device comprises first and second multipliers M_1 and M_2 , receiving said stereo difference signal (L-R) modulated 38 kHz subcarrier as well as respectively first and second identical, substantially square wave mixing signals MS_1 and MS_2 having a 38 kHz repetition or mixing frequency $f_o = f_c$ and 50% duty cycle, mutually differing in phase by a phase angle $\Delta\phi$ of 60 degree. The mixing of the subcarrier modulated
20 stereo difference signal (L-R) with said first and second mixing signals MS_1 and MS_2 will result not only in the wanted stereo difference signal (L-R), but also any undesired information signal in the region of $3f_o = 114 \text{ KHz}$ being demodulated into baseband, due to the third order harmonic components $3f_o$ of said mixing signals MS_1 and MS_2 . However, the so obtained undesired baseband information signal occurring
25 in the output signal of said first multiplier M_1 is identical but phase opposite to the undesired baseband information signal occurring in the output signal of said second multiplier M_2 , hereinafter being referred to as third order interferences. By using an adder circuit following upon said first and second multipliers an addition of the wanted stereo difference signals (L-R) simultaneously with a compensation of the
30 unwanted third order interference at the outputs of the first and second multipliers M_1 and M_2 is being obtained. The adder circuit therewith delivers the desired baseband stereo difference signals (L-R) free from unwanted third order interferences.

In practice, this known multiplier device appears to maintain its suppression of third order interferences when being used with a mixing frequency f_o deviating from the carrier frequency f_c , also at relatively high values of f_c and/or f_o causing the waveform of said mixing signals to deviate considerably from rectangular. This provided that the mutually identical correspondence in waveforms and the 50% duty cycle of said first and second mixing signals MS_1 and MS_2 are preserved.

However, due to the ongoing demand for higher performance/price ratio the suppression of third order interferences as provided for in the above known multiplier device does not suffice anymore.

On itself, a stereodecoder is known from US patent 5,220,607, in which third and fifth order harmonic interferences are prevented from occurring in the output signal of a multiplier device by using a mixing signal having a specifically defined, rectangular multi-level waveform. This known interference suppression depends on the accuracy in maintaining said specific waveform. At frequencies increasing above the 38 kHz stereo difference signal (L-R) subcarrier frequency said waveform will be deteriorated by a.o. increasing non-linearities, making this known interference suppression unsuitable for receiver applications.

It is an object of the present invention to provide a robust, low cost multiplier device allowing for an effective suppression of all undesired higher order interferences, which is very well suitable for use in receivers for converting an RF antenna input signal into an IF signal.

Another object of the invention is to allow for a robust and low cost implementation.

Now, therefore, a multiplier device comprising first to n^{th} multipliers M_1 to M_n for multiplying a carrier modulated information signal with first to n^{th} mutually phase shifted and identical, substantially square wave mixing signals MS_1 to MS_n with 50% duty cycle according to the invention is characterized by n being greater than 2, outputs of said multipliers M_1 to M_n being respectively coupled through weighting circuits W_1 to W_n with respective fixed weighting factors WF_1 to WF_n to an adder circuit, said mixing signals MS_1 to MS_n having respective phase angles φ_i corresponding to $\varphi_i = i * \Delta\varphi$, said weighting factors WF_i corresponding to the sine value of said respective phase angles $\varphi_i = i * \Delta\varphi$ with $\Delta\varphi$ being the mutual phase

difference between each two phase consecutive mixing signals corresponding to $\pi/(n + 1)$ and i varying from 1 to n .

The invention is based on the insight that cancellation of interferences of any higher order in a multiplier device can be obtained with a properly chosen number n of multipliers and same number of mutually identical mixing signals with 50% duty cycle by using only the multiplication gains and phase angles of said mixing signals as parameters.

By applying the above measure according to the invention, the mutually identical 50% duty cycle waveform of the n mixing signals are chosen to be substantially rectangular, allowing for a multiple use of mutually identical costeffective non-linear multipliers, logic and other circuitry and adequate operation at high frequencies. The multiplication gains are being provided for with said weighting circuits W_1 to W_n , allowing for the use of mutually identical multipliers with mutually identical gain, which are easy to implement.

By choosing the mutual phase shift between the mixing signals and the weighting factors WF_1 to WF_n of the weighting circuits W_1 to W_n in accordance with the above the above measure according to the invention harmonic interferences up to the $(2n-1)$ order are being suppressed. Or, vice versa, by choosing the number n to correspond to $(N+1)/2$ an elimination of all harmonics up to the N^{th} order from the output of said adder circuit in accordance with the invention is obtained .

Another preferred embodiment of a multiplier device according to the invention which allows for a costeffective implementation is characterized by said mixing signals MS_1 to MS_n being derived from a local oscillator signal with frequency f_0 through an arrangement of fixed phase shift means and/or frequency divider means.

A robust and accurate implementation of an embodiment of a multiplier device according to the invention is characterized by a local oscillator circuit supplying an oscillator signal with frequency f_0 to a serial arrangement of first to n^{th} phase shifting means, each providing a fixed phase shift of $\Delta\phi$ and supplying respectively mixing signals MS_1 to MS_n to said first to n^{th} multipliers M_1 to M_n .

Preferably, said local oscillator circuit generates a clock control signal with clock frequency $n * f_0$ being supplied through a frequency divider with dividing factor n to said serial arrangement of first to n^{th} phase shifting means, each of said first to n^{th}

phase shifting means comprising a D-flip-flop being clock controlled by said clock control signal and providing said fixed phase shift of $\Delta\phi$.

These and further aspects and advantages of the invention will be discussed more in detail hereinafter with reference to the disclosure of preferred embodiments, and in particular with reference to the appended Figures that show:

Figure 1, a multiplier device according to the invention;

Figure 2A, a graph for deriving the mutual phase difference between two phase consecutive mixing signals and weighting factors WF1 to WF3 in a multiplier device according to the invention for $n=3$;

Figures 2B to 2D, waveforms of identical, substantially square wave mixing signals MS_1 to MS_3 with 50% duty cycle for $n=3$;

Figure 3A, a graph for deriving the mutual phase difference between two phase consecutive mixing signals and weighting factors WF1 to WF4 in a multiplier device according to the invention for $n=4$;

Figures 3B to 3D, waveforms of identical, substantially square wave mixing signals MS_1 to MS_n with 50% duty cycle for $n=4$;

Figure 4A, a mixing signal generator for generating first to n^{th} mutually phase shifted and identical, substantially square wave mixing signals MS_1 to MS_n with 50% duty cycle according to the invention;

Figure 4B, deviations of mixing signals, which do not affect proper operation of the multiplier device according to the invention.

Figure 1 shows an embodiment of a multiplier device (M_1 - M_n , W_1 - W_n , ADD) according to the invention used in a receiver front end. The receiver front end comprises an RF antenna ANT being coupled to an RF input unit RFI supplying an RF antenna input signal with an RF carrier frequency f_{RF} in common to first to n^{th} multipliers M_1 to M_n , n being 3 or more. The RF antenna input signal is being demodulated therein into an intermediate frequency (IF) signal with an IF carrier frequency f_{IF} . Said first to n^{th} multipliers M_1 to M_n receive from a mixing signal generator MSG respectively first to n^{th} mutually phase shifted and identical, substantially square wave mixing signals MS_1 to MS_n with 50% duty cycle. Outputs of said first to n^{th} multipliers M_1 to M_n are respectively coupled through weighting

circuits W_1 to W_n with respective fixed weighting factors WF_1 to WF_n to an adder circuit ADD. The adder circuit ADD provides at its output said IF signal without harmonic interferences up to the $(2n-1)^{th}$ order. According to the invention, said mixing signals MS_1 to MS_n have respective phase angles φ_i corresponding to $\varphi_i = i * \Delta\varphi$, whereas said weighting factors WF_i correspond to the sine value of said respective phase angles $\varphi_i = i * \Delta\varphi$ with $\Delta\varphi$ being the mutual phase difference between each two phase consecutive mixing signals corresponding to $\pi/(n+1)$ and i varying from 1 to n .

By choosing n to correspond to $(N+1)/2$ elimination of all harmonics up to the N^{th} order from the output of said adder circuit ADD is being obtained.

Figure 2A shows how to determine the mutual phase difference between two phase consecutive mixing signals and the weighting factors WF_1 to WF_3 in a multiplier device according to the invention for an elimination of the third, fifth and seventh order harmonic interferences, i.e. for $n=3$.

Figures 2B to 2D show respectively first to third mutually identical, substantially square wave mixing signals MS_1 to MS_3 with 50% duty cycle having respective phase angles φ_1 to φ_3 corresponding to $\Delta\varphi$, $2\Delta\varphi$ and $3\Delta\varphi$. Herein $\Delta\varphi$ is the mutual phase difference between each two phase consecutive mixing signals corresponding to $\pi/(n+1)$, for $n=3$ being $\pi/4$. The weighting factors WF_1 to WF_3 correspond to the sine value of said respective phase angles φ_1 to φ_3 , i.e. $\sin \pi/4$, $\sin \pi/2$ and $\sin 3\pi/4$ or 0.7, 1 and 0.7.

The use of these mixing signals MS_1 to MS_3 with $\Delta\varphi$ being $\pi/4$ and weighting factors WF_1 to WF_3 equalizing respectively 0.7, 1 and 0.7, causes all higher order harmonic interferences up to the fifth order to be eliminated from the output signal of the adder circuit ADD.

Figure 3A shows how to determine the mutual phase difference between two phase consecutive mixing signals and the weighting factors WF_1 to WF_4 in a multiplier device according to the invention for an elimination of the third, fifth and seventh order harmonic interferences, i.e. for $n=4$.

Figures 3B to 3D show respectively first to fourth mutually identical, substantially square wave mixing signals MS_1 to MS_4 with 50% duty cycle having respective phase angles φ_1 to φ_4 corresponding to $\Delta\varphi$, $2\Delta\varphi$, $3\Delta\varphi$ and $4\Delta\varphi$. Herein $\Delta\varphi$ is the mutual

phase difference between each two phase consecutive mixing signals corresponding to $\pi/(n + 1)$, for $n=4$ being $\pi/5$. The weighting factors WF_1 to WF_4 correspond to the sine value of said respective phase angles ϕ_1 to ϕ_4 , i.e. $\sin \pi/5$, $\sin 2\pi/5$, $\sin 3\pi/5$ and $\sin 4\pi/5$ or 0.59, 0.95, 0.95 and 0.59.

- 5 The use of these mixing signals MS_1 to MS_4 with $\Delta\phi$ being $\pi/5$ and weighting factors WF_1 to WF_4 equalizing respectively 0.59, 0.95, 0.95 and 0.59 0.7, 1 and 0.7, causes all higher order harmonic interferences up to the ninth order to be eliminated from the output signal of the adder circuit ADD.

10 Figure 4 A shows an embodiment of a mixing signal generator MSG as used in the mixer device of Figure 1, comprising a local oscillator circuit LOC generating a clock control signal with clock frequency $n * f_0$ being supplied through a frequency divider FD with dividing factor n to a serial arrangement of first to n^{th} phase shifting means, each of said first to n^{th} phase shifting means $D1$ to Dn , comprising a D-flip-flop being clock controlled by said clock control signal and providing said fixed phase shift of
15 $\Delta\phi$. Mixing signals MS_1 to MS_n are being supplied from respectively outputs of said first to n^{th} phase shifting means $D1$ to Dn to said first to n^{th} multipliers M_1 to M_n .

20 Figure 4B shows a mixing signal waveform which deviates from rectangular due to the smoothing effect of one (bold line) or two (bold and dotted lines) timeconstants occurring at high frequencies. Such substantially square waveform mixing signals do not jeopardize the suppression of undesired higher order harmonic interferences in a multiplier device according to the invention provided they are mutually identical.

25 In the above, the present invention has been described with reference to a disclosure and drawings that illustrate a preferred embodiment. Persons skilled in the art would however from inspecting thereof recognize various changes and amendments to such preferred embodiment. For example, the mixing signal generator MSG may well use other configurations of delay circuits and/or frequency dividers to obtain the above mixing signals according to the invention.

30 Therefore, the disclosure herein should be considered by way of example, rather than by way of restriction, and the due scope of the present invention should be determined from the Claims appended hereto.